Baryon number fluctuation and critical end point

Shi Yin,[1] Rui Wen,[1] and Wei-jie Fu[1,*]

[1] *School of Physics, Dalian University of Technology, Dalian, 116024, P.R. China*

We investigate the relationship between the peak value of baryon number fluctuation kurtosis and the critical baryon chemical potential. At the same time, the freeze-out curves under different position of the critical end point. We control the position of the critical end point by include the fermion vacuum fluctuation gradually. This work is done under the low energy Polyakov-quark-meson model with the functional renormalization group approach.

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INTRODUCTION

The location of the critical end point (CEP) of the QCD phase diagram is a popular research direction in the field of high energy physics. However, the physical property at high baryon chemical potential is hard to study in both theoretical and experimental. In the experimental field, the Relativistic Heavy Ion Collider (RHIC) that provides us with a lot of experimental data [1–3].

BARYON NUMBER FLUCTUATIONS AND THE FERMION VACUUM FLUCTUATION

The calculation of the baryon number fluctuation can be done using the following formula,

$$\chi_n^B = \frac{\partial^n}{\partial(\mu_B/T)^n}\frac{p}{T^4}\,, \tag{1}$$

In which the $\mu_B = 3\mu$ is the beryon chemical potential that is triple of the quark chemical potential. Then we can obtain the first to fourth order of the beryon number distribution,

$$\chi_1^B = \frac{1}{VT^3}\langle N_B\rangle\,, \tag{2}$$

$$\chi_2^B = \frac{1}{VT^3}\langle(\delta N_B)^2\rangle\,, \tag{3}$$

$$\chi_3^B = \frac{1}{VT^3}\langle(\delta N_B)^3\rangle\,, \tag{4}$$

$$\chi_4^B = \frac{1}{VT^3}\Big(\langle(\delta N_B)^4\rangle - 3\langle(\delta N_B)^2\rangle^2\Big)\,, \tag{5}$$

The meaning of the angle brackets stands for the average value, and the δN_B stands for the difference between the N_B and $\langle N_B\rangle$ which reads $\delta N_B := N_B - \langle N_B\rangle$.

For the purpose of comparing our calculation with the experimental results, we divide the fourth and second order of the baryon number fluctuations to get the kurtosis which is the observable in the experiments, e.g.,$\kappa\sigma^2 = \chi_4^B/\chi_2^B$. Here we investigate the relationship of the maximum value of the kurtosis and the fermion vacuum fluctuation.

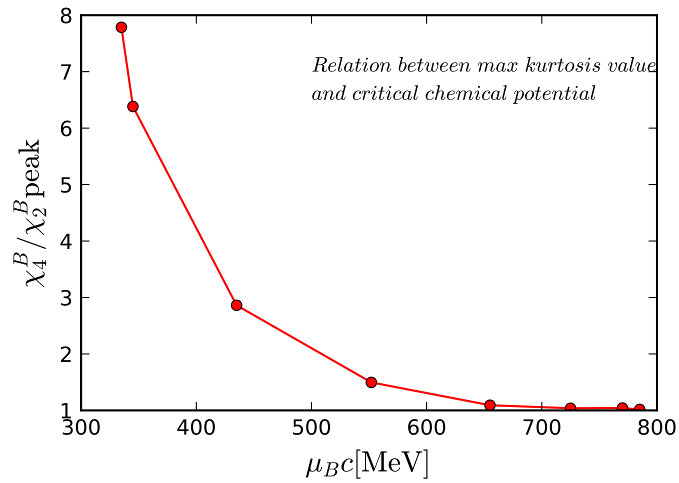

FIG. 1. The relation between the maximum baryon number fluctuation kurtosis value and the baryon chemical potential of the critical end point.

In this work we add a new cutoff scale into the functional renormalisation group flow equation to restrict the fermion vacuum fluctuation and study the behavior of the position of the critical end point under the different cutoff.

From the previous work of the low energy effective theory under the FRG, the flow equation of the effective potential contain the full contribution of the fermion vacuum part throughout the integral interval which is cover from the infrared point to the ultraviolet point. The effect of the fermion vacuum contribution is studied in the mean field approximation, see [4].

POLYAKOV-QUARK-MESON MODEL

This work is done under the two quark flavor Polyakov-quark-meson model. We give the effective action

$$\Gamma_k = \int_x \Big\{ Z_{q,k}\bar{q}\Big[\gamma_\mu\partial_\mu - \gamma_0(\hat{\mu}+igA_0)\Big]q + \frac{1}{2}Z_{\phi,k}(\partial_\mu\phi)^2 + h_k(\rho)\bar{q}\big(T^0\sigma + i\gamma_5\vec{T}\cdot\vec{\pi}\big)q + V_k(\rho) - c\sigma \Big\}, \tag{6}$$

In the PQM model under the FRG approch we study the symmetry of the fields by the effective potential $V_k(\rho)$, then the flow equation of the effective potrntial is the center of our calculation. The flow equation can be written as

$$\begin{aligned}\partial_t V_k(\rho) =& \frac{k^4}{4\pi^2}\big[(N_f^2-1)l_0^{B,4}(\bar{m}_{\pi,k}^2,\eta_{\phi,k};T) \\ &+ l_0^{(B,4)}(\bar{m}_{\sigma,k}^2,\eta_{\phi,k};T) \\ &- 4N_cN_f l_0^{(F,4)}(\bar{m}_{q,k}^2,\eta_{q,k};T,\mu)\big],\end{aligned} \tag{7}$$

The $l_0^{(F,4)}$ in the flow equation stands for the fermion threshold function.

RESULTS AND SUMMARY

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* wjfu@dlut.edu.cn

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